"practical engineers or business men, thus bringing to bear on their teaching, not only the general education gained at school and their thorough knowledge of theoretical science, but also their practical experience of the workshop and business life."

These are but a few of the vital questions with which this valuable report is concerned. We heartily commend the volume to all who are interested in improving the home supply of technical education until it is not only on a level with that of Germany and Austria, but well in advance.

When we turn to the second of the reports, that concerned with the place in English secondary education of preparatory schools for boys, we are confronted with another stage in the preparation of the citizen for the duties of life. As every one knows, probably, the preparatory school undertakes the education, up to about fourteen, of the boy destined for our great public schools. Generally, after some five years at the public school, this fortunate son of well-to-do parents proceeds to either Oxford or Cambridge to continue his education. It is interesting to inquire as to the share science takes in the work of a preparatory school. It may be stated parenthetically that in a volume of 531 pp. only some sixteen pages are devoted to the teaching of mathematics and natural science together, though it is true nine of the sixteen are given to the latter.

It must be said at once that any science teaching at all in preparatory schools is the exception rather than the rule. To quote Mr. Archer Vassall, of Harrow, who deals with the subject in the official publication before us, "tentative efforts in scientific instruction have been made, and are still in progress at many of them"—and that is all that can be said. But there is nothing surprising about this. Since the sole function of the preparatory school is to prepare for the public school, those subjects only which are in demand in the second will be taught in the first, and, to quote Mr. Vassall again, "in public schools the teaching of science has only recently begun to take reasonable shape," a condition brought about by the regulations governing the award of University scholarships. So that to ensure an improved condition of things in the preparatory school men of science must bend their efforts towards securing reforms at Oxford and Cambridge.

Mr. Vassall's short article is chiefly concerned with a sketch of a suitable preparatory school course in natural science. In common with modern ideas he insists upon the need of individual practical work, and very properly urges that the study of science might well begin with what he calls "kindergarten physics." This mode of procedure has for some years been followed in higher grade boards schools, and in those other secondary schools which have adopted the syllabus of the Headmasters' Association. But we think Mr. Vassall is wrong in excluding chemistry from his preliminary course, for there are many excellent exercises which are in no way dangerous. Anyhow, a beginning has been made with science in preparatory schools, and if the masters will acquaint themselves with the results of experience in schools of other grades, we shall soon hear that science has gained for herself a more honourable place.

A. T. SIMMONS.

THE FIGURE OF THE EARTH.[1]

THE United States Coast and Geodetic Survey has just published a quarto volume containing an account of the transcontinental triangulations and measurements of an arc of the parallel in latitude 39°. It also has ready for publication the manuscript giving the result of an oblique arc in the eastern part of the United States. Both are contributions of great length and among the first of their kind in America.

Before entering upon the detail of the two arcs it may not be out of place to state that in order to obtain a measure of the dimensions of the earth, as represented by a spheroid, that is, by a surface generated by the rotation of an ellipse about its minor axis, it is essential that we should be in possession of at least two arcs or of an equivalent thereof. For combinations of two arcs of the meridian, their mean latitudes should differ widely; the same is true for the combination of two arcs of the parallel. We may also obtain an arc of the meridian with one of the parallel, but in every case the measures should be of considerable extent. Arcs of less than 5° (about 556 km., or 345 st. miles) would now be regarded as short ones. It has been stated that one of the arcs is an oblique arc, and as it possesses a great range of latitude and also of longitude and is supplied with a large number of astronomical measures, it is of itself sufficient for the deduction of values for the dimensions of the earth. Furthermore, it may be remarked that for any relatively small part of the earth's surface an osculating spheroid may be determined, as, for instance, was done for our oblique arc. Such a spheroid has the property that its surface is in best accord, as regards curvature, with the actual or physical one, the latter considered as a mathematical surface of equilibrium and generally known as geoid.

The definition of an osculating spheroid thus implies that the sum of the squares of the difference between the various astronomic and geodetic measures be a minimum. The mathematical treatment of the combination of the arc measures differs according to their nature, whether they are extended in a certain direction or whether large areas are covered, but in its generality it is necessarily laborious.

The salient points of the two arcs measured by the U. S. Coast and Geodetic Survey and the results reached may now be briefly stated. First, the arc of the parallel in latitude 39°.[1] It extends from Cape May, N.J., on the Atlantic coast, to Point Arena, Cal., on the Pacific coast, and ranges over 48° 46′ of longitude, with a linear development of about 4225 kilometres, or 2625 st. miles. The triangulation is supported by ten base lines with an aggregate length of 53½ st. miles, the longest or Yolo base being 10·9 miles in length, one half of these lines having a smaller probable error of measure than one part in a million. A characteristic of the triangulation is its rigidity imparted to it by quadrilaterals and other polygons. In crossing the Rocky Mountains, many of its sides exceed one hundred miles in length, and there is one side reaching to a length of 294 km., or 183 st. miles; the altitude of many of the stations is also considerable, reaching to 4300 metres, or 14 108 feet, in the case of Pike's Peak, and to 14,421 feet at Mount Elbert. All geometrical conditions subsisting in the triangulation are satisfied by adjustment, inclusive of the required accord of the base lines, so that the same length for any given line is found no matter from what line one may start. This involved much heavy work; for instance, the triangulation adjustment between the Salina and the El Paso base demanded the simultaneous solution of ninety-nine normal equations (with as many unknowns). In addition, the figures required the evolution of a correction to each of the two hundred and twenty-five observed directions.

Coming to the astronomical measures, we have distributed over or near the arc one hundred and nine latitude stations, occupied almost exclusively with zenith telescopes; there are, also, seventy-three azimuth stations, various methods having been used, and lastly we have twenty-nine telegraphically determined longitudes. These, of course, are of paramount importance for an arc of the parallel. There cannot be too many longitude stations in consequence of that great stumbling-block in geodesy, the local deflections of the vertical or plumb-line. These deflections of the zenith from a normal direction have been divided into two groups—those which are regional or manifest themselves with marked common features over thousands of square miles, and those which are quite local and greatly depend upon the surface features immediately surrounding them.

These deflections, even in level countries, average about 2·5″; but in mountainous regions this deflection is greatly surpassed. Thus we find for deviation of the plumb-line at Patmos Head station 12″ to the north, at Colorado Springs 25″ to the west, at Salt Lake City about 17″, and at Ogden about 15″ to the east, at Genoa Station, Nev., nearly 29″ to the west, the quantities depending to some extent on the spheroid of reference; but their amount and direction are obviously well accounted for by the position of known attracting masses. In connection with this, continental attraction may manifest itself and be recognised by the astronomical amplitude of the longitudes of extreme stations of a long arc being in excess of the corresponding geodetic amplitude. The matter cannot be further pursued here in detail, but it may suffice to state that the average curvature of the equipotential surface of the geoid along the parallel of 39°

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[1] Abridged from a paper on recent contributions by the United States Coast and Geodetic Survey to our knowledge of the earth's shape and size, by Mr. C. A. Schott, in the *National Geographic Magazine*, New York.

[1] U. S. Coast and Geodetic Survey; H. S. Pritchett, Superintendent. The Transcontinental Triangulation and the American Arc of the Parallel. By C. A. Schott, Assistant, Coast and Geodetic Survey, Washington, D.C., 1900.

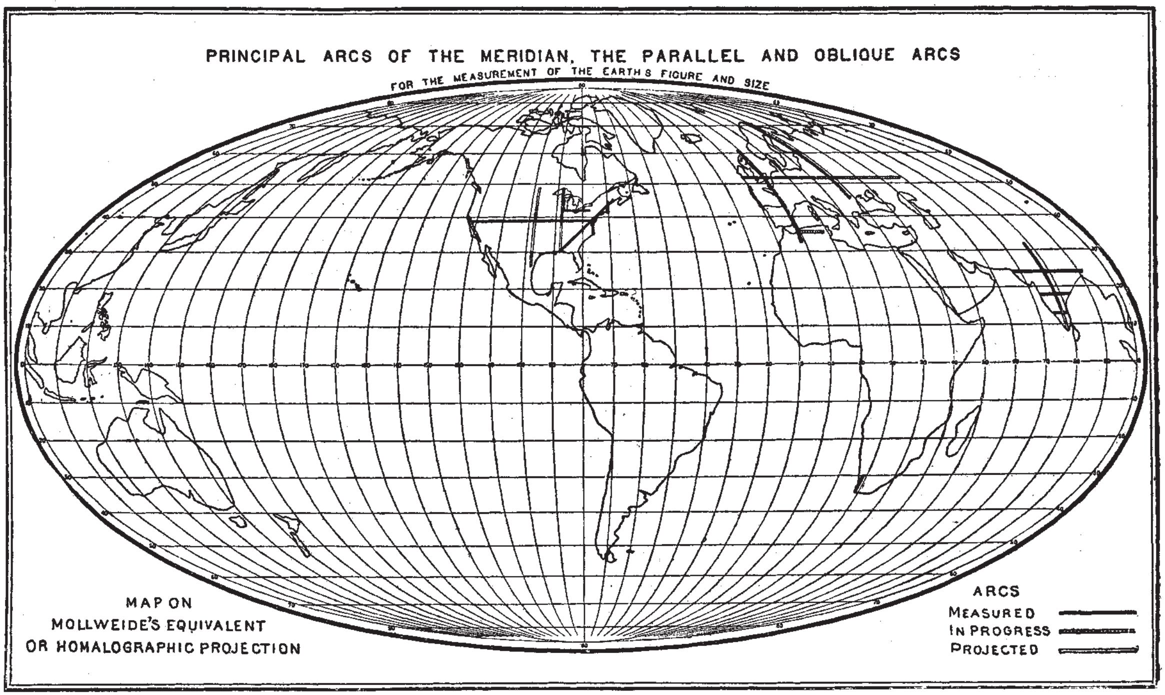
approaches for about four-sevenths of the arc from its eastern end closely to that of the Clarke spheroid; whereas, for the remaining three-sevenths, or for the region across the Rocky Mountains to the Pacific, the curvature comes more nearly to that of the Besselian spheroid. In the published paper two tables are given containing the results needed for combination with any other arc and, in conclusion, some preliminary rough combinations of American arcs are presented; all of which point to a reference spheroid of larger dimensions than those of the Besselian and are in favour of continuing the use of Clarke for reference.

The second arc under consideration extends from Calais, Me., in the north-east and opposite the Canadian boundary, to the Gulf of Mexico, and terminates at New Orleans, La. It is known as the Eastern Oblique Arc of the United States. Its length is 2612 km., or 1623 statute miles; its difference of latitude is 15° 1′, and of longitude 22° 47′. The general direction is therefore favourable, and the length ample to secure fair results for an osculating spheroid. In the main the triangulation follows the Appalachian chain of mountains; in Western North Carolina and Eastern Tennessee it bifurcates, leaving an oval space between the two branches. The length of sides depends upon six base lines, and in general the development is closely accommodated to the hypsometric and other natural conditions along the course. It includes among its stations the two highest points in the eastern part of the United States, viz. Mount Washington, N.H., rising to about 1920 metres, or 6300 feet, and Mount Mitchell, N.C., rising to about 2038 metres, or 6687 feet.

The adjustment of the whole triangulation is effected precisely as explained in the use of the arc of the parallel; the small reduction to the sea-level of the observed horizontal directions, on account of the altitudes sighted, was only applied when exceeding 0·05″. The principal labour of adjustment was demanded by the necessity of bringing into accord the measured lengths of the Fire Island, the Massachusetts and the Epping base lines, and fulfilling the geometrical conditions of the intervening net of triangles. This demanded the satisfying of fifty-seven conditions and involved the simultaneous solution of an equal number of normal equations and the working out of 131 corrections of observed directions. Of astronomical measures we have seventy-one latitute stations, seventeen longitude stations, and fifty-six azimuth stations, tolerably well distributed over the whole extent of the arc. The latitudes, as were those of the arc of parallel, were corrected for height of station or curvature of the vertical and for variation of pole according to Dr. Chandler's and Dr. Albrecht's researches. The same scrutiny as before had been extended to the deflections of the vertical, both regional and local. Partly on account of avoiding unnecessary labour, but principally on account of the crowding together of astronomical stations in certain very limited localities, and all of them, therefore, partaking of the deflections characteristic of this area, the total number of astronomical stations admitted into the final equations for the determination of the best spheroid were thirty-six for latitude, fourteen for longitude, and thirty-four for azimuth, or eighty-four conditions in all.

These eighty-four differences between the astronomical and geodetic results constitute the data needed for a new determination of a spheroid; next the functional relations between the positions of these stations upon the reference spheroid to the earth's equatorial radius and to the compression of the polar axis had to be established.

The final normal equations contain, therefore, four unknown quantities, viz. the correction to the meridional deflection of the vertical at the initial or reference station of the oblique arc; second, the corrections to the deflection of the vertical, in the plane of the prime vertical, at the same place; third, correction to the equatorial radius of the reference spheroid; and last, the correction to its compression.


PRINCIPAL ARCS OF THE MERIDIAN, THE PARALLEL AND OBLIQUE ARCS
FOR THE MEASUREMENT OF THE EARTH'S FIGURE AND SIZE

In the combination of conditional equations arising from observations of a different nature, the question of their relative weights must be considered. In the present case, four assumptions were made and the consequent normal equations solved, viz. for equal weights, for weights one-half, one-third and one-fourth to the azimuth equations, the latter being necessarily inferior to the equations derived from latitudes and longitudes. A comparison of these four results showed that it was of small consequence which of these hypotheses was finally adopted, since the corrections to the equatorial radius of the reference spheroid were practically the same for any of these hypotheses, and nearly the same could be said of the resulting compressions. The weight one-third to each of the azimuth equations was finally decided upon, and the resulting dimensions of an osculating spheroid were found to be:—Equatorial radius, 6,378,157 ± 90 metres; compression, 1/304·5 ± 1·9. The equatorial radius, therefore, differs but 49 metres from Clarke's value of 1866 adopted on the Survey, while the Besselian value is apparently too small by 809 metres. On the other hand, the compression or the ratio of the difference of the equatorial and polar semi-axes to the former is in favour of Bessel's spheroid, of which the compression is 1/299·2; that is, one more closely approaching a sphere.

In the present state of our knowledge there is no reason to suppose that the curvature of the northern part of America differs any more from that of a general spheroid derived from arcs of all kinds so far measured than local ones in either hemisphere differ among themselves. A comparison of a number of such locally adopted spheroids will bring to evidence the local deformities in the shape of the earth's equilibrium surface and furnishes the geodesists endless material for the study of the earth's actual figure.

The manuscript concludes with a comparative table of the dimensions of several spheroids which of late have come more into prominence. It is as follows:—

Spheroid of	Equatorial radius, *a*, in metres.	Polar semi-axis *b*, in metres.	*a*−*b*.	Compression (*a*−*b*)/*a*.
Bessel, 1841. From ten arcs of the meridian and total amplitude 50° 34′	6,377,397	6,356,079	21,318	1/299·15 ± 3·15
Clarke, 1858. Special spheroid for surface of Great Britain and Ireland; range of latitude 12°, the same in longitude; seventy-five astronomic stations	6,378,494 ± 90	6,355,746	22,748	1/280·4 ± 8·3
Clarke, 1866. From five meridional arcs, of total amplitude 76° 35′	6,378,206	6,356,584	21,622	1/295·0
Clarke, 1880. From five meridional arcs and longitudinal measures, total amplitude 88° 59·8′ (equatorial degrees)	6,378,249	6,356,515	21,734	1/293·5
United States Coast and Geodetic Survey, 1900. Eastern oblique arc of the United States; total length, 23° 31′, and eighty-four astronomic stations	6,378,157 ± 90	6,357,210	20,947	1/304·5 ± 1·9
Harkness, 1891. From "The Solar Parallax and Related Constants," Washington, 1891, p. 138. From a variety of sources	6,377,972 ± 125	6,356,727 ± 99	21,245	1/300·2 ± 3·0

N.B.—The ± indicates probable errors.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—A valuable collection of Greek papyri from Oxyrhyncus and the Fayûm has been presented to the University library by the Egypt Exploration Fund.

Dr. A. C. Haddon, F.R.S, University lecturer in ethnology, and professor of zoology in the Royal College of Science, Dublin, has been elected to a junior fellowship at Christ's College.

THE King's Speech to the Commons at the opening of Parliament on Thursday last contained the announcement that "Legislation will be proposed to you for the amendment of the law relating to education."

SOCIETIES AND ACADEMIES.

LONDON.

Royal Society, February 7.—"The Integration of the Equations of Propagation of Electric Waves." By A. E. H. Love, F.R.S.

The equations of propagation of electric waves, through a dielectric medium, involve two vector quantities, which may be taken to be the electric force and the magnetic force. Both the vectors are circuital; and the several components of them satisfy the partial differential equation of wave propagation, viz. $\phi = c^2\nabla^2\phi$, c being the velocity of radiation.

Owing to the circuital relations, certain known solutions of the partial differential equation of wave propagation are not available, for representing the components of the vectors. A very general system of *particular* solutions, which are available for this purpose, is obtained. These include solutions corresponding to two types of sources of electric radiation:—The sources of one type are similar to infinitesimal Hertzian vibrators, being related in the same way to an axis, but the dependence of the emitted radiation on time is arbitrary; the sources of the other type are obtained therefrom by interchanging the *rôles* of the electric and magnetic forces.

The general integrals of the equations would express the values of the vectors, at one place and time, in terms of their values, at other places and times. To find such integrals, we require (1) sets of particular solutions, which tend to become infinite, in definite ways, in the neighbourhood of chosen points; (2) a theorem of reciprocity, connecting the values, on any chosen surface, of two sets of solutions; (3) the limiting form, assumed by the theorem of reciprocity, when the solutions of one system have the assigned character of infinity at a given point. The solutions required for the first step are among those already found; the theorem of reciprocity is obtained by a modification of the process by which the fundamental equations can be deduced from the Action principle; and the limiting form of the theorem is found by adapting a process due to Kirchhoff. The result is that the radiation which arrives at a chosen point may be regarded as due to a distribution of imagined sources of radiation upon an arbitrary closed surface, separating the point from all the actual sources of radiation. The imagined sources are of the two types previously specified; and the directions of their axes, and the intensities of the radiation sent out from them, are determined simply and directly by the values, on the surface, of the vectors involved in the propagation of the waves.

The general theorem is applied to the problem of the passage of radiation through an aperture, and the result is utilised to determine the rate of decay of the vibrations of a condensing system. The example of a condenser, with concentric spherical conducting surfaces, the outer conducting sheet being perforated by a small circular aperture, is worked out in detail; and the results suggest that the maintenance of the vibrations depends on the screening action of the outer conductor rather than on the largeness of the capacity of the condenser.

Anthropological Institute, February 4.—Annual General Meeting.—Mr. C. H. Read, president, in the chair.—On a ballot the following were elected to office for the ensuing year:—President: Prof. A. C. Haddon, F.R.S. Vice-presidents: A. J. Evans, W. Gowland, Prof. G. B. Howes. Hon. Treasurer: A. L. Lewis. Hon. Secretary: J. L. Myres. Council: Sir T. H. Holdich, Sir C. E. Peek, Messrs. G. M. Atkinson, H. Balfour, W. Crooke, Prof. D. J. Cunningham, W. L. H. Duckworth, R. W. Felkin, H. O Forbes, J. G. Garson, E. S. Hartland, T. V. Holmes, E. F. im Thurn, A. Keith, R. B. Martin, M.P., R. H. Pye, E. G. Ravenstein, Prof. W. Ridgeway, W. H. R. Rivers and F. C. Shrubsall. After reading and discussion of the reports of the treasurer and council, the retiring president proceeded to give his address. After alluding to the death of Her Majesty Queen Victoria and paying a tribute to Lieut.-General Pitt-Rivers, an ex-president of the Institute, Prof. Max Müller, Miss Kingsley and other distinguished Fellows who had been removed by death, he went on to call attention to the progress made by anthropology, more especially in the British Empire, during the past year. A joint memorial of the Folk-lore Society and the Institute had been presented to the Government, urging the theoretical and practical importance of an inquiry into the status of native races in South Africa. In India, in combination with the census, a scheme for a partial ethnographical survey had been called into existence, over the working of which the Hon. H. H. Risley would preside. He hoped that in England we should soon have chairs of anthropology at all the important teaching